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Plantation Performance Related to Canadian Fire Weather Index System: 10-Year Consequence of a Time-of-Planting Study in the Coast–Interior Transition Zone

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Plantation Performance Related to Canadian Fire Weather Index System: 10-Year Consequence of a Time-of-Planting Study in the Coast–Interior Transition Zone

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ABSTRACT

Douglas-fir 2+0 bareroot stock was planted at five locations in the Coast–Interior Transition Zone in the Vancouver Forest Region. Six plantings were conducted per year over a 2-month period from late spring to mid-summer each year for 3 years (1977–1979). Plantation performance was related to the Canadian Fire Weather Index System (FWI). Earliest plantings had the highest survival and growth. Seedlings planted under climatic conditions with a Buildup Index (BUI) greater than 50–60 displayed lower survival and performed more poorly than seedlings planted under less droughty conditions. After 10 years, height increment differences related to planting time persist. Early stresses, regardless of their origin, may well have long-term consequences on plantation performance.

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1 INTRODUCTION

Plantation performance[1] of Douglas-fir in the Coast–Interior Transition biogeoclimatic subzones[2] (CWHvh, CWHds, and IDFww; Klinka *et al.* 1984) has generally been poor. Planting time has frequently been cited as one reason for this. Sites are often inaccessible until late spring when soil moisture deficits and climatic evaporative demands are increasing. Such climatic conditions result in higher moisture requirements by seedlings, especially as seedlings are flushing and actively growing. As well, stock quality may have declined during the stock's prolonged storage (Ritchie 1982). As a result of these physiological stresses, many questions arise concerning how late planting can take place and still achieve acceptable survival and performance.

1.1 Initial Project Objective

The initial objective of this project was to examine plantation performance by time of planting in relation to site and climatic conditions. Although Cleary *et al.* (1978) have provided some useful guidelines for considering climate conditions at the time of planting, their guidelines do not explicitly address the trend in climatic conditions before planting. The Canadian Forest Fire Weather Index System (FWI), however, does use previous climatic conditions to calculate a fire danger rating (Canadian Forestry Service 1984; Turner and Lawson 1984).

Although the FWI is not designed as a planting window index, the variables measured and parameters derived are similar to those used for predicting seedling physiological stresses. The intent of the initial project was to develop a probabilistic model of survival as a function of the FWI. Because the index has been routinely calculated and is familiar to field personnel, its use in current planting programs would be feasible and attractive. Past FWI data could also be used as a source of information for determining reasons for past plantation performance problems.

1.2 Remeasurement Objectives

In time, site and climatic factors will, it is expected, eventually come to dominate seedling performance, as initial differences in seedlings disappear because of various cultural, handling, and planting factors. However, many studies still suggest that initial treatment differences may profoundly affect the long-term growth of different species. These include the effects of:

- time of planting on lodgepole pine and white spruce (Pollack and LePage 1986; Scagel *et al.* 1990)
- site preparation on ponderosa pine (Thompson 1974)
- stocktype on Douglas-fir (Pendl and D'Anjou 1983; Krumlik and Bergerud 1984), red pine (Mullin 1974, 1980), white pine (Mullin 1980), white spruce (Mullin 1980), and amabilis fir (Pendl and D'Anjou 1990)
- nursery practices: soil amendments, on ponderosa pine (Thompson 1974); lifting date on Douglas-fir (Sloan 1989)
- storage duration and condition on red pine (Mullin 1974) and Douglas-fir (Sloan 1989)
- planting effects on red pine (Mullin 1974), white pine (Mullin 1980), and white spruce (Mullin 1980)
- seedling size on Douglas-fir (Pendl and D'Anjou 1983; Krumlik and Bergerud 1984).

Many of these studies also indicate that growth and survival are linked: poor growth is often accompanied by poor survival. The objectives of the experiment remeasurement were to determine whether:

1. performance effects due to planting time were evident after 10 years; and
2. growth and survival were linked.

---

[1] Performance is used here in the sense defined by Hobbs (1988) and includes survival, growth, and form of seedlings. It does not directly consider stocking.

[2] Subzone codes refer to current MOF Biogeoclimatic convention (CWHvh = CWHd; CWHds = CWHc; IDFww = IDFe).

2 METHODS

2.1 Location

The research plots are located in the Pemberton Valley and the Fraser Canyon (Fig. 1). Four locations per year were planted, two in each geographic area. Each location was divided into two sites, each of which had two 50-tree rows per planting date. Although 12 locations were initially involved in the experiment, the ages of the various experiments and survival limited remeasurement to only five locations (Table 1). The locations cover the range of biogeoclimatic subzones of the Coast–Interior Transition Zone. All locations had been freshly clearcut-logged and slashburned. This particular harvesting and site preparation treatment is not considered silviculturally appropriate for all locations (Klinka *et al.* 1984). Each had an amphimesic moisture/nutrient regime. No vegetation management treatments were applied to any of these locations.

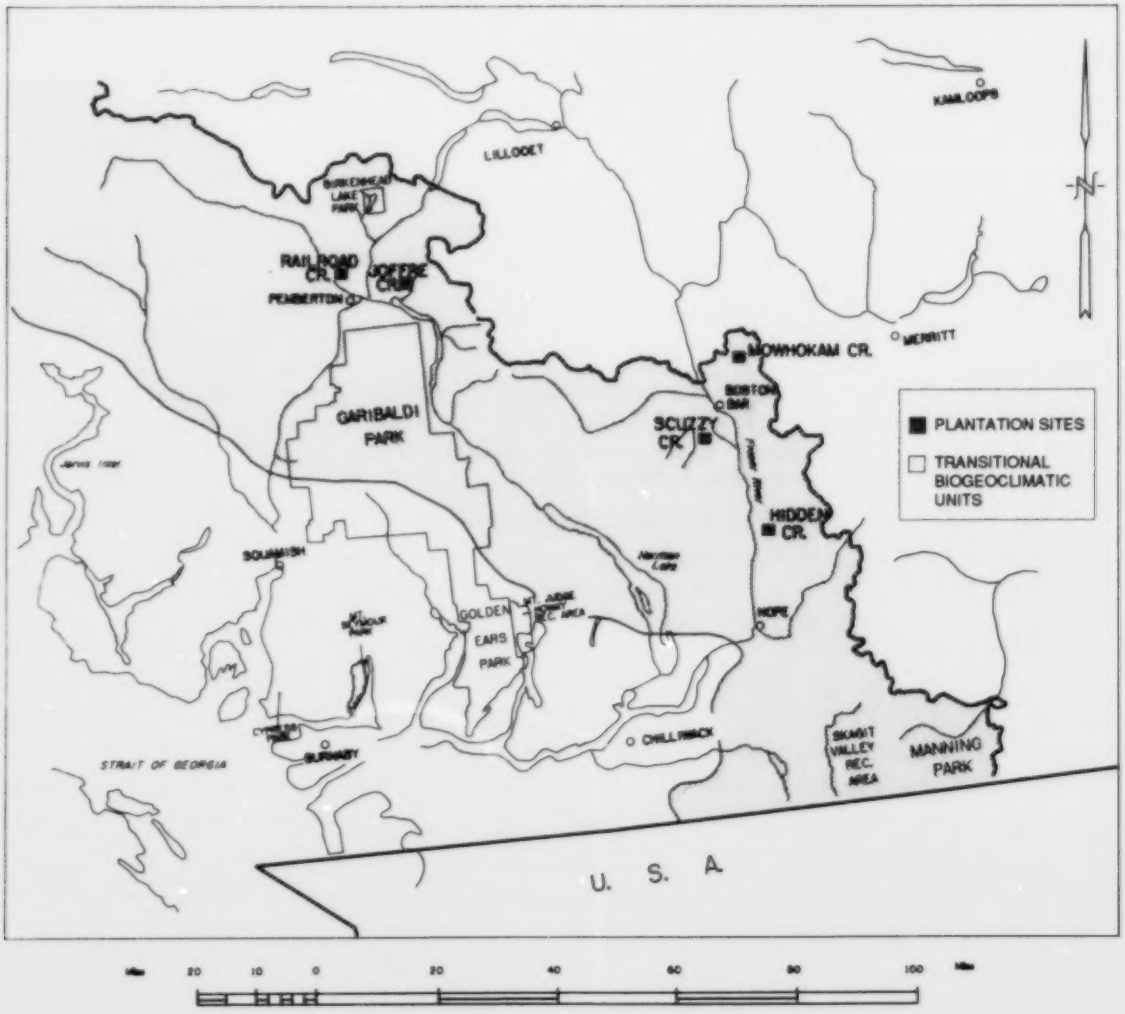

FIGURE 1. Locations remeasured in 1988.

TABLE 1. Site descriptions of locations used in remeasurement

Location	Year	BGCZ[a]	Elevation (m ASL)	Edatope	Aspect (°)	Slope (%)	Site history	
							Logged	Burned
Pemberton Valley								
Railroad Creek	1977	CWHvh	960–1130	3–4/ C	W–WNW	50	1975	1976
Railroad Creek	1978	IDFww	760–840	3/ C	SW–SE	35–40	1976	1977
Joffre Creek	1977	CWHvh	1120	2–3/ B	SW	35	1975	1976
Joffre Creek	1978	CWHvh	780–830	3/ C	SE	30	1976	1977
Joffre Creek	1979	IDFww	640	3/ C	W–SW	10	1977	1978
Fraser Canyon								
Scuzzy Creek	1977	CWHvh	900	4/ C	W	30	1975	1976
Hidden Creek	1979	CWHds	600	3–4/ C	FLAT	0	1977	1978
Mowhokum Creek	1979	IDFww	1040	3–4/ C	SE	10	1977	1978
Weather stations								
Boston Bar	1977–1989	IDFww	170					
Pemberton	1970–1986	IDFww	90					

[a] After Klinka *et al.* 1984.

2.2 Planting

Six plantings (all by mattock) were performed every year, beginning in early May and ending in late July (Table 2). The planting dates used in this experiment are later than most planting dates used for the Coast–Interior Transition. Planting should have been started earlier, but was delayed because of funding problems.

TABLE 2. Planting dates. The actual planting date varied by year and location

Planting no.	Date
I	May 3–10
II	May 17–26
III	May 31–9
IV	June 14–23
V	June 28–7
VI	July 12–22

2.3 Seedlings

All seedlings used on these plots were 2+0 bareroot Douglas-fir. Both seedlots were local collections, selected from larger, operationally grown crops (Table 3). Seedlings were all grown at a single nursery in the Lower Mainland. They were lifted in late December and cold-stored until planting. To check stock quality, trees were planted in a nursery outplanting plot at the Ministry of Forests' Green Timbers Nursery. Root growth capacity (Burdett 1987) and seedling moisture potential (Jolly 1985) were also determined. No problems were detected with the stock on the basis of either nursery outplanting plots or laboratory procedures.

2.4 Climate Monitoring

Weather stations were set up at each of the locations before the seedlings were planted. Climate was monitored at these locations only during the year of planting. The climate variables measured were:

Daily air —

- Temperature
- Relative humidity
- Precipitation
- Wind speed and direction

Soil —

- Temperature at 10, 20, and 30 cm
- Moisture

TABLE 3. Douglas-fir bareroot 2+0 seedlots planted and remeasured sample size (N)

Year	Location	Seedlot	No.
Pemberton Valley			
1977	Railroad Creek	1019	1197
1977	Joffre Creek	1019	614
1978	Railroad Creek	1647	155
1979	Joffre Creek	1647	1388
Fraser Canyon			
1977	Scuzzy Creek	1647	558
1979	Mowhokam Creek	1647	1066
1979	Hidden Creek	1647	1407

These measurements were summarized with the use of the Canadian Fire Weather Index System (FWI) and the Buildup Index (BUI). The BUI is a cumulative expression of rainfall and atmospheric evaporative demand, and it is used to estimate fuel drying for forest fire weather hazard assessment. The lower the BUI, the better the soil and weather conditions should be if plantation establishment is to be successful. The BUI estimates from individual locations have been pooled for each year and are given in Figure 2 for each of 3 years of the experiment. More detailed analysis of the microclimate data of individual locations is given in Spittlehouse and Goldstein.[2]

FIGURE 2. Mean BUI for experimental sites in the year of planting. The BUI estimates are pooled over all experiment locations for each of the planting years. The dashed vertical lines indicate the planting dates for that year. The dashed horizontal lines indicate the critical BUI range of 50–60. Notice the date in each year that the BUI exceeds the 50–60 BUI range.

On the experimental locations, the seasonal change of BUI is similar in each year: low BUI values in May, increasing through June, and increasing to a substantial drought in mid-August through mid-September. However, there are also some noticeable differences between the 3 years. Mid-summer BUI's in 1977 and

[2] D. Spittlehouse and M.J. Goldstein. 1990. Comparison of the seedling planting windows model with fire weather buildup index. B.C. Min. For., Victoria, B.C. In preparation.

1979 exceeded 150. The BUI of the early planting dates in 1978 were higher and fluctuated more than those in 1977 and 1979. The last three plantings in 1977 and 1978 were conducted under a much higher BUI than in 1979.

The BUI calculated from long-term Ministry of Forests' fire weather stations at Pemberton and Boston Bar (Fig. 3) indicate year-to-year variations similar to those for the BUI calculated from climate stations at the experiment locations. The BUI's are higher at the fire weather stations than at the experimental locations, reflecting the lower elevation of the fire weather stations. The Boston Bar station is substantially drier earlier and longer than the Pemberton Station (Fig. 4). The long-term BUI suggests that Pemberton Station had summer droughts that were normal, but the years the experiments were established, particularly 1978, had drier springs than usual.

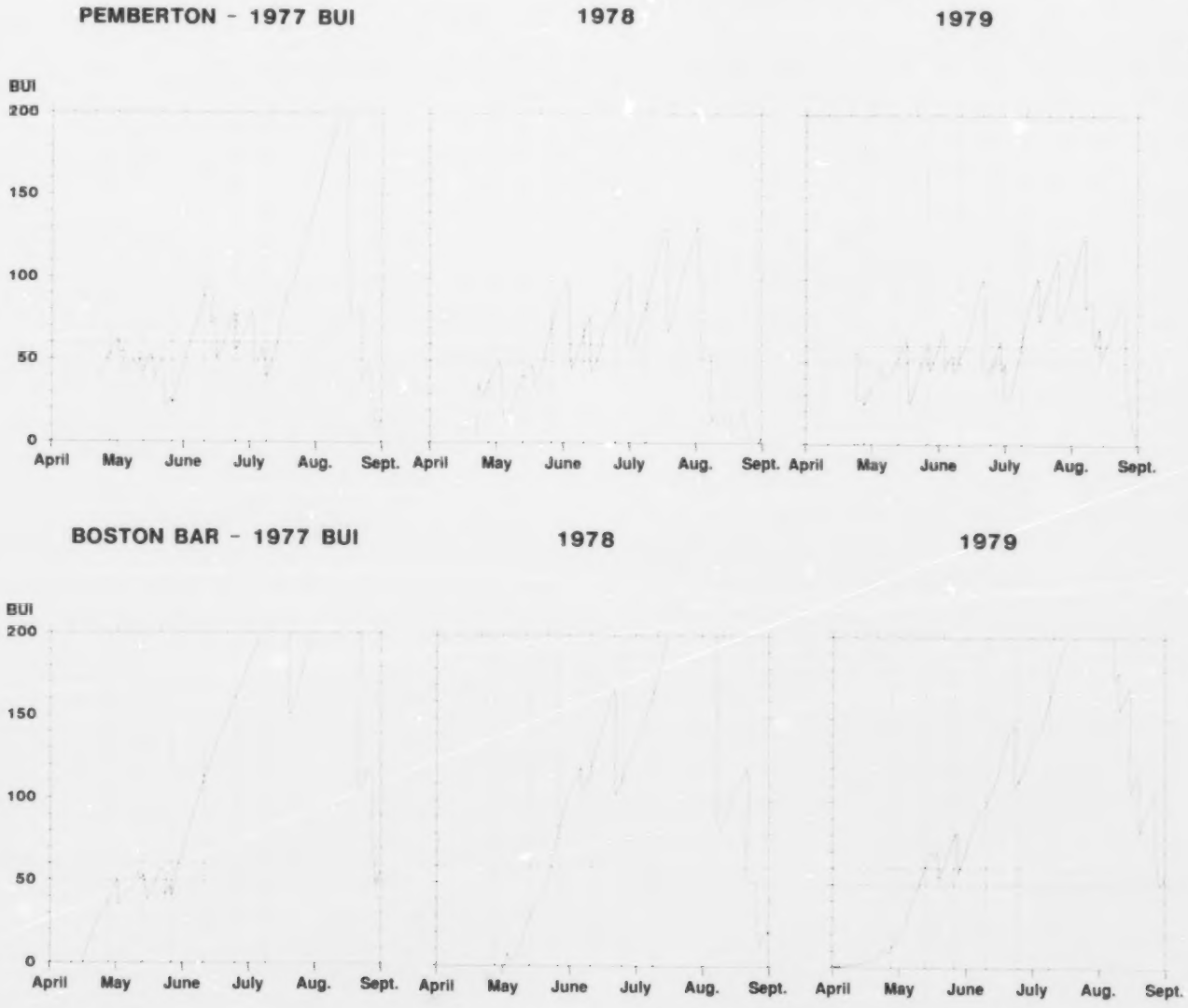

FIGURE 3. The BUI for Pemberton and Boston Bar fire weather stations for 1977, 1978 and 1979. Boston Bar weather station is consistently drier earlier than the Pemberton station. Dashed vertical lines indicate the planting dates for that year. The dashed horizontal lines indicate the critical BUI range of 50–60.

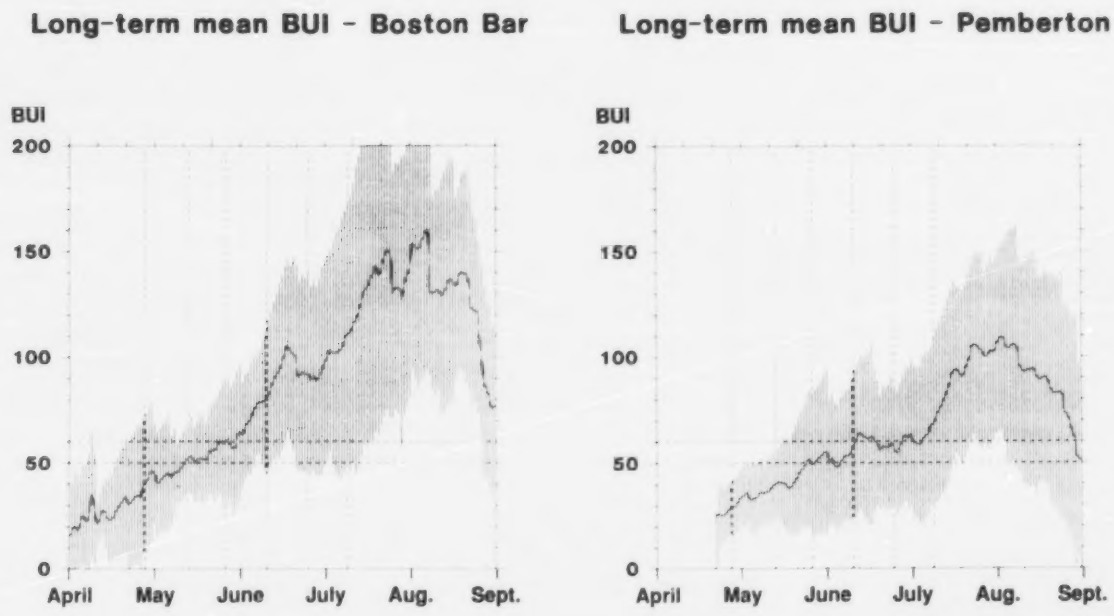

FIGURE 4. Long-term mean BUI for Pemberton and Boston Bar long-term fire weather stations. The BUI calculated for Pemberton (1970–1986) and Boston Bar (1977–1989) fire weather stations. Vertical lines around the mean are the standard error of the mean for each day. Dashed vertical lines indicate the planting dates for that year. The dashed horizontal lines indicate the critical BUI range of 50–60.

2.5 Seedling Assessment and Measurement

2.5.1 Initial survival assessment

All assessments and measurements were made on an individual-tree basis by a stake-tree survey method (Stein 1978). Trees were assessed every 2 weeks until the end of the planting year. Survival was reported 6 weeks after planting, each fall for the succeeding 2 years, and in the fall of 1988.

2.5.2 Remeasurement strategy and location selection

Condition, form, and growth of seedlings were measured in fall 1988. Total sample size in this remeasurement is given in Table 3. The form variables used in data collection included:

Growth variables:

- Increment – 10-year increment
- Height – 10-year total height
- Diameter – diameter at 30 cm

Form variables:

- Stem forking
- Leader dieback
- Multiple leaders

Stem breakage
Stem bent or swept
Lammas growth of current leader
Frost damage
Browsing damage
Stem scar
Basal sweep or bend to stem
Appressed stem
Necrotic foliage
Needles loss (generally root rot)
Chlorotic foliage

Generally the trials were in excellent condition. Documentation from the working plan, establishment reports, and previous field notes were checked during field inspection. Ambiguous row assignment and trees were excluded from measurement. The tight spacing of the plantation made it easy to determine seedling mortality and to continue assessments on a stake-tree basis. Only plots in which all rows could be unambiguously identified were remeasured.

As the age of the experiments range from 10 to 12 years, the height of the trees after their 10th growing season had to be measured by the reconstruction of the last few years of growth increments. Special attention was paid to determining lammas growth incidence, to prevent erroneous measurements. Diameter growth could not be reconstructed and instead has been presented as 10-, 11-, or 12-year results.

2.6 Data Analysis

Multi-year studies are logistically complex, and invariably many factors can be confounded. In this experiment the principal confounding factors are:

1. experimental location and planting year (different locations were used in different years);
2. planting year and climate (different planting years have had different climates);
3. planting date and storage duration (later planting dates used stock that had been cold-stored longer than earlier planted stock);
4. planter and planting time (the same planters could not be used throughout the experiment; only one planter was assigned to each 50-tree row).

Because of the confounding of factors, observations were pooled to address the research objectives.

Box plots, used in a variety of forestry-related articles (Bergerud 1987; Titus 1987; Scagel *et al.* 1989, 1990), present variations. These box plots offer more information about the data than do means and standard errors and are an appropriate graphic device where both central tendency *and* variation in the data are of interest (Appendix 1).

3 RESULTS AND DISCUSSION

3.1 Survival

3.1.1 Time of mortality

Time of planting and year of planting were the most important factors determining survival. Mortality was evident within 6 weeks of planting (Fig. 5). All trees flushed the year they were planted. There was no mortality in the nursery outplanting plots. The early occurrence of mortality indicated that mortality was likely site-related.

The largest change in mortality, about 25%, occurred within a year after planting. Further mortality occurred between the first and second growing seasons, but was much less than the mortality in the first year. Survival varied substantially between years, but was less than acceptable by remeasurement in 1988. The worst survival (34% average) occurred in the 1978 plantings. Survival in the experimental plantings was generally less than operational survival (Fig. 6) because of the late planting of the experiment (Plate 1).

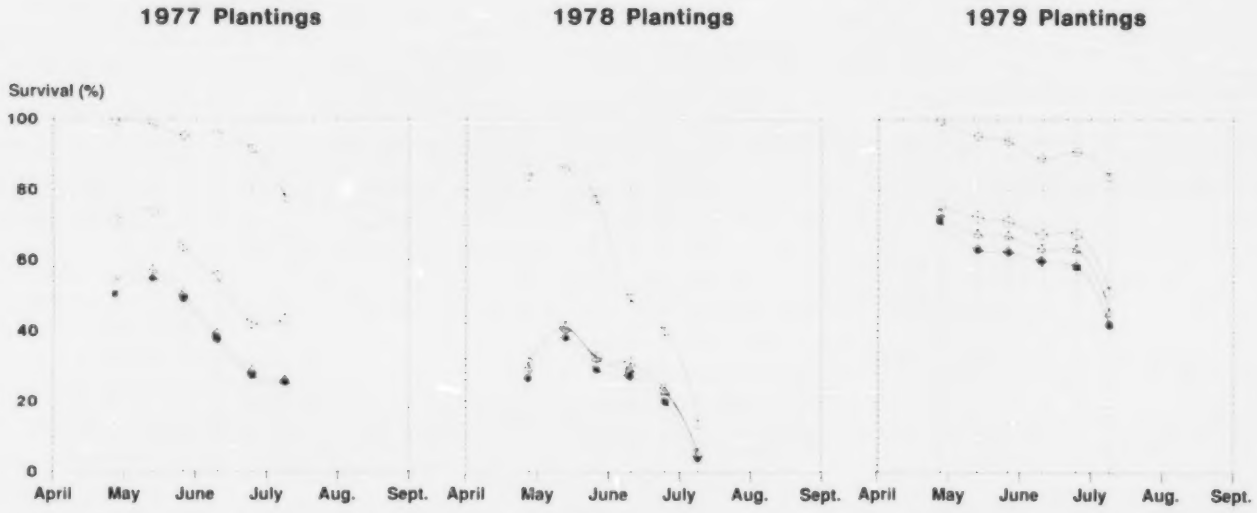

FIGURE 5. Year-to-year survival variation. Mean 6-week, 1st-year, 2nd-year, and survival until 1988. In each year, survival has been pooled over all locations for each planting date. Horizontal dashed line is 80% survival and corresponds to the limit of commercially acceptable mortality. Vertical dashed lines indicate the planting dates. Standard errors are about 10%. Plotting symbols used: □ – 6-week survival; ○ – 1-year survival; △ – 2-year survival; ● – 12-year survival.

3.1.2 Planter effect

It was not possible to examine planter effects for all locations and planting times. Where they could be evaluated, the effects were clearly evident in the survival data. Pooled over all locations and all planting dates, the differences between planters accounted for a 10% mean difference in mortality. Generally, the later the planting the more pronounced the survival differences between planters. Poor planting was accentuated by unfavourable climate. For later plantings, difference between planters was as much as 25%, depending on the location. Planter effects were related to site heterogeneity and plantability and planter experience.

3.1.3 Time of planting effect

Even 10 years after planting, the effect of planting date was substantial. Early mortality trends were indicative of longer-term patterns. Similar patterns were observed on all locations: the earlier the planting, the better the initial survival. Each year, survival was noticeably diminished by the fourth planting. By then, BUI's *at planting* had increased to between 50 and 60. This threshold of 50–60 BUI is clearly illustrated in Figure 7 for the 6-week survival. However, the significance of this threshold at planting for determining longer-term mortality is not as strong because of climatic conditions *following planting*.

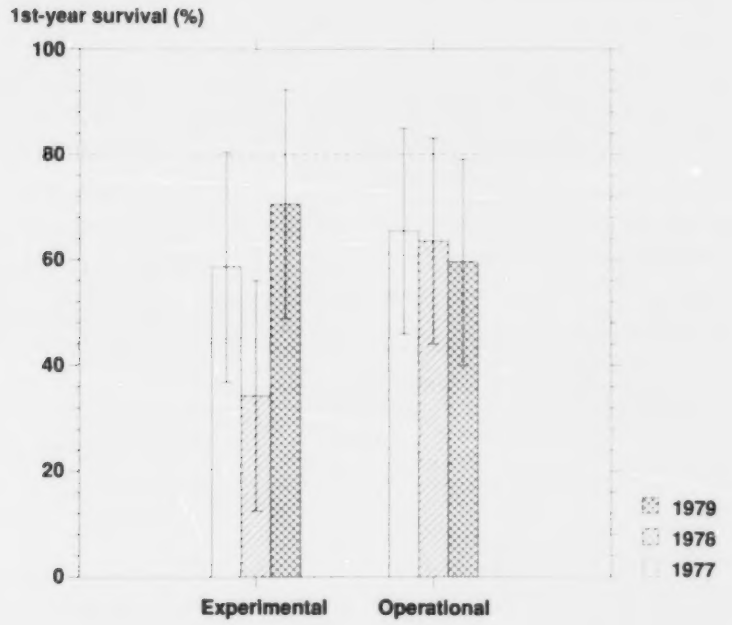

FIGURE 6. Comparison of operational and experimental survival. Comparison of mean operational and mean experimental plantations of 2+0 bareroot coastal Douglas-fir throughout the Coast–Interior Transition Zone. The operational plantation survival is based on the same seedlots used in the experiment. Experimental results pool all locations and all planting times for each year. Survival is based on survival at the end of the first growing season. Dashed line is 80% survival and corresponds to the limit of commercially acceptable mortality. Standard errors are about 10%.

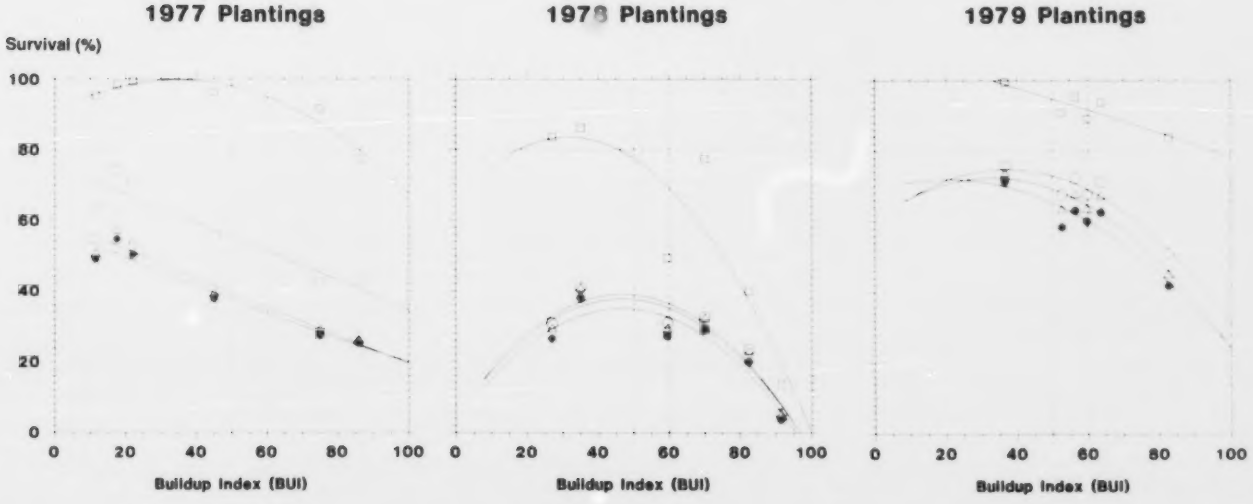

FIGURE 7. Survival in relation to BUI. Comparison of 6-week, 1st-year, 2nd-year, and survival until 1988 with BUI at planting. In each year, survival has been pooled over all locations for each planting date. Horizontal dashed line is 80% survival and corresponds to the limit of commercially acceptable mortality. The dashed vertical lines indicate the critical BUI range of 50–60. Plotting symbols used: □ – 6-week survival; ○ – 1-year survival; △ – 2-year survival; ● – 12-year survival.

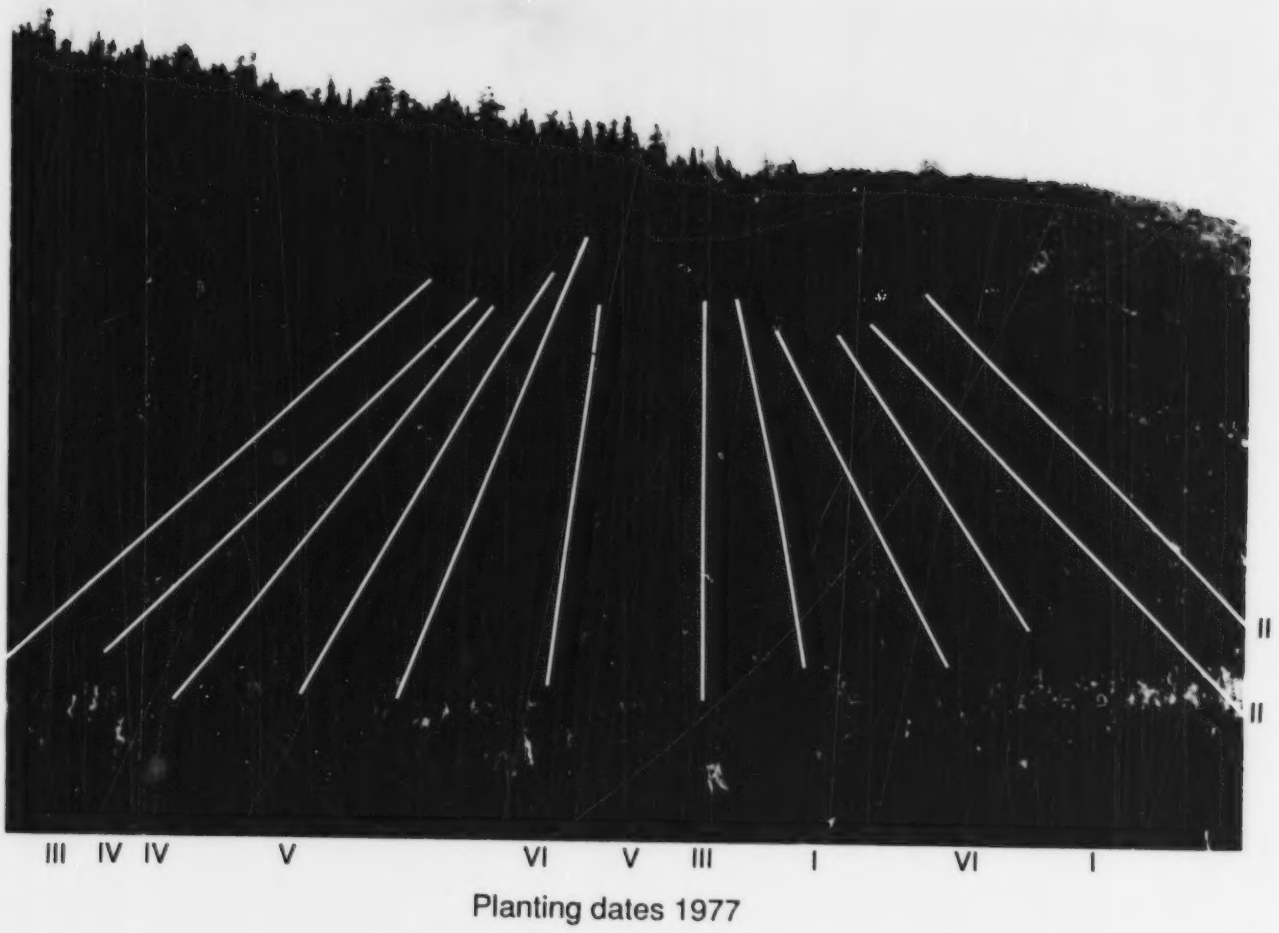

PLATE 1. Experimental plantations were 12 years old at the time of the photograph. This site was slashburned in 1976 and operational plantings failed before it was finally successfully replanted with Engelmann spruce. The relation between planting date, survival, and growth is clearly evident in the photograph. The numbers below the photograph are the planting dates given in Table 2.

Both Pemberton and Boston Bar climate stations indicate that BUI's exceed the 50–60 range by the end of May every year of the experiment. The long-term average BUI (Fig. 4) also suggests that BUI typically exceeds the 50–60 range by the end of May. There is substantial year-to-year variation: BUI can exceed the 50–60 range as early as mid-April or as late as mid-July. Notice also that by the start of September the BUI has again declined to the 50–60 range.

3.1.4 Location effect

Within a planting year, all locations had very similar 6-week survivals (i.e., survival declined with planting date; Fig. 8). Location differences in survival appeared after 1 year and became increasingly expressed with age. These differences appeared to increase due to climate differences and vegetation competition.

3.2 Growth

3.2.1 Location effect

Location explains most of the variation in growth (Fig. 9). Pemberton Valley locations performed better than Fraser Canyon locations. The same trend has been noted for operational plantations (H. von Hahn, pers. comm.). The location-to-location variation is so large that planting-time effects are obscured. Within each location, however, there is a significant planting-time effect on total growth, diameter, and even annual increment. Box plots of these factors are given in Appendix 1 for each location.

3.2.2 Time of planting

Total height, 10th-year increment growth, and diameter show the same pattern as survival (Appendix 1): the earlier the planting the better the total growth and growth increment. This trend is evident on all locations although the degree of expression varies. Form differences were location-related and caused by snow press or root rot, but not related to planting time.

The differences between first and last plantings at some locations are trivial (e.g., Joffre Creek, 1977), but at other locations (i.e., Joffre Creek, 1979) they are very large. In addition to total height differences, height increment differences between planting times still exist after 10 years. Not only have the earliest plantings grown the most, but they continue to outgrow later plantings. Unlike for survival, there was no noticeable planter effect on growth. On these locations, planter effect is a determinant of survival and not of growth.

4 CONCLUSIONS

The findings of this study contradict the assumption that initial seedling differences due to planting time and storage duration will eventually disappear as a result of location and climatic factors. The findings do, however, corroborate the observation that poor growth is often accompanied by poor survival. The environment at planting is strongly implicated in 10-year performance: the poorest seedling performance and survival is found when an on-site BUI greater than 50–60 occurs.

5 OPERATIONAL CONSIDERATIONS

5.1 Long-term Consequences

Small delays in planting appear to have significant practical long-term consequences. Assuming that small initial differences will eventually be homogenized by the site conditions and environment is a liberal prediction about plantation performance. A more acceptable, but admittedly conservative, assumption about seedling performance should be adopted for plantations in the Coast–Interior Transition Zone. That is: early stresses, regardless of their origin, may have long-term economic consequences. Careful attention to stock handling and planting details should be made to ensure the reliability and productivity of plantation.

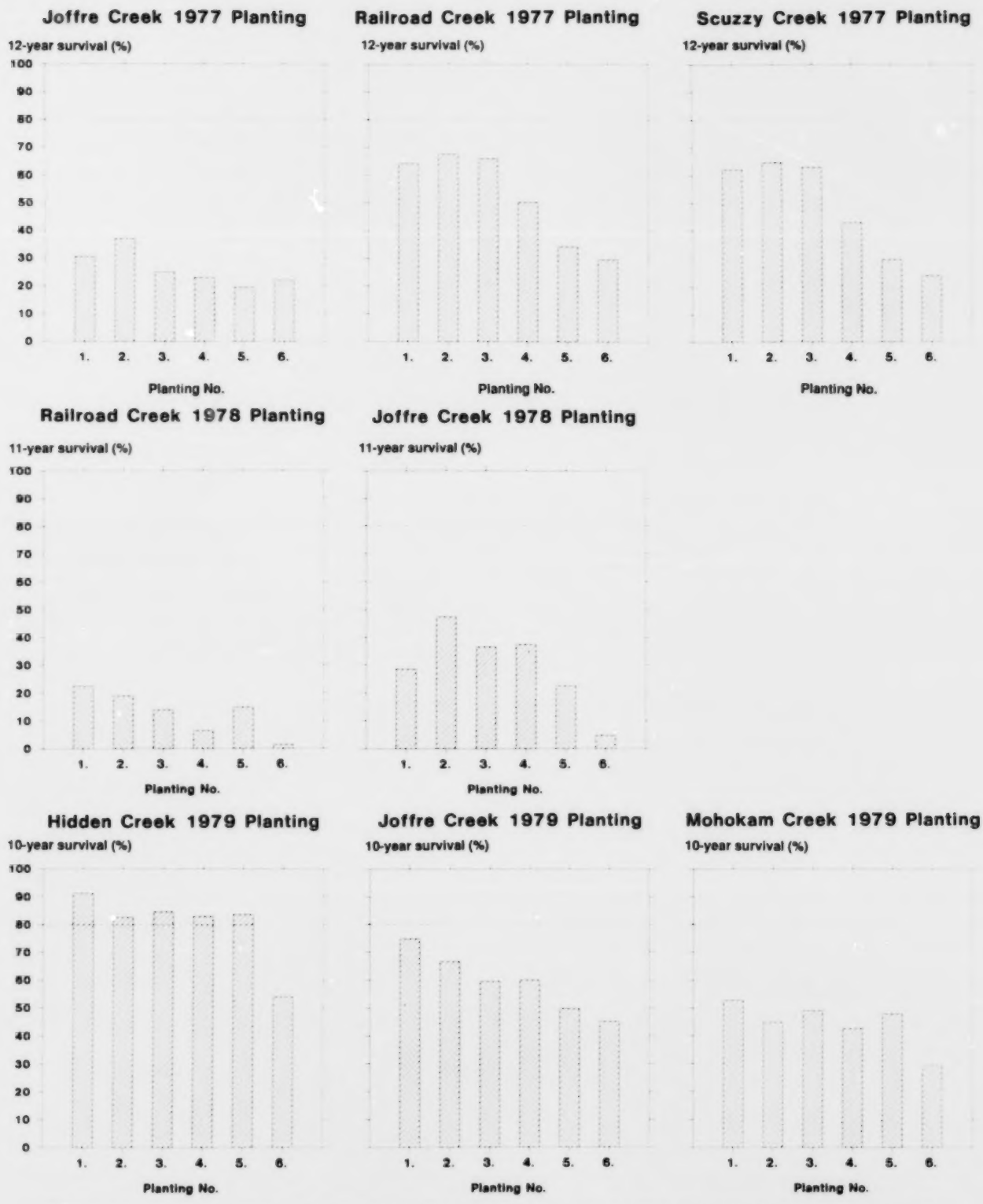

FIGURE 8. Mean location survival in 1988. For each location, survival has been pooled over all rows and locations for each planting date. Horizontal dashed line is 80% survival and corresponds to the limit of commercially acceptable mortality.

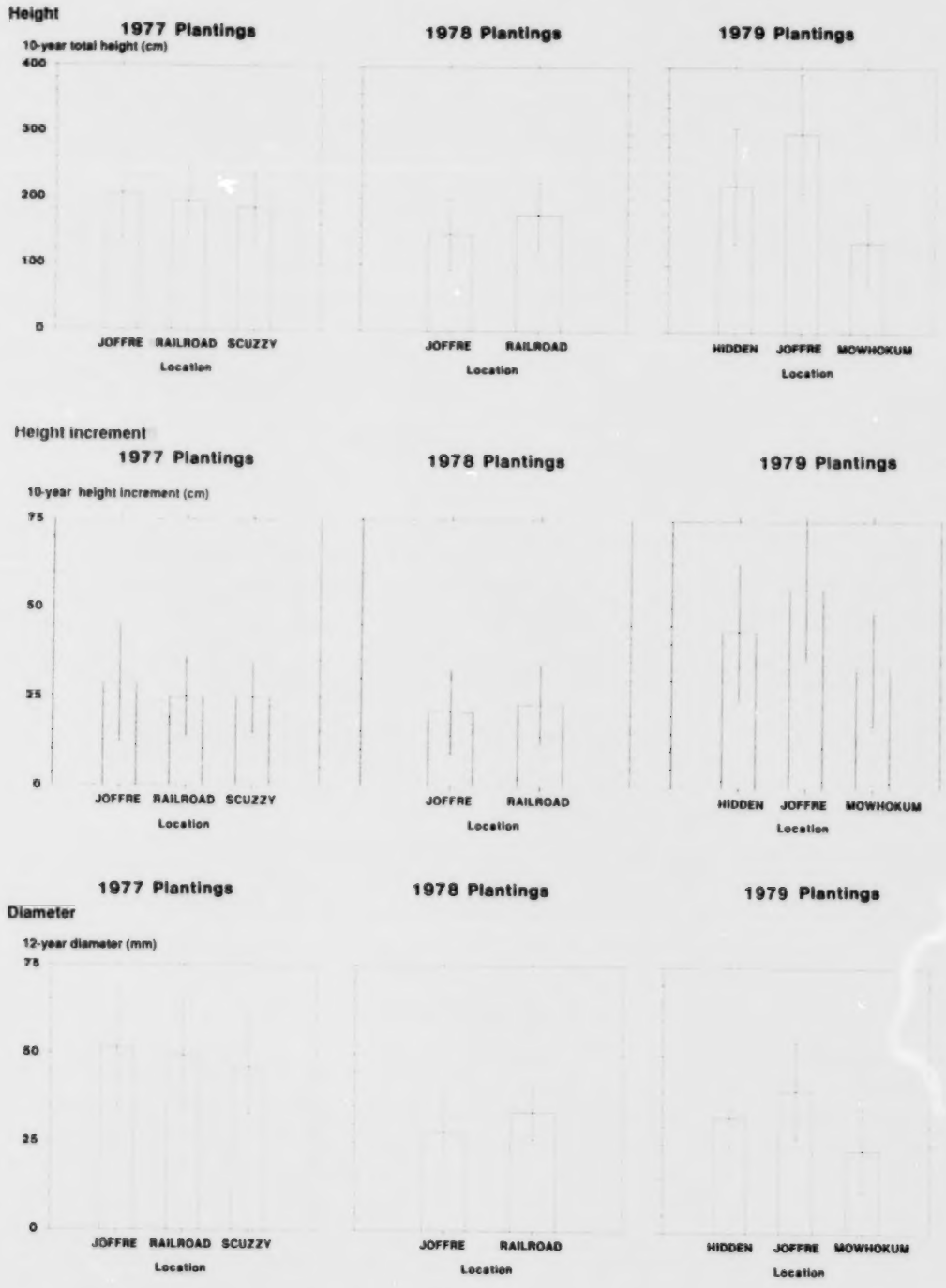

FIGURE 9. Mean growth of planting years. Shown are 10-year total height, 10-year height increment, and total diameter in 1988 for separate planting years. Bars represent mean values; error bars are standard errors around the mean. Analyses pool all crop trees from all plantings at all locations in a given planting year.

5.2 Using BUI as a Planting Hazard Index

The BUI can be used as a first approximation to selecting a planting time.

A BUI of 50–60 appears to be the upper limit of acceptable climatic conditions (before drought) at planting. When using the index as a determinant of planting the following must also be taken into consideration:

1. the trend in BUI before planting; and
2. anticipated trend in BUI following planting.

Long-term BUI records (Fig. 4) can be used to set priorities in planting operations such that planting can be scheduled before an expected severe BUI. Provided BUI has been increasing slightly (not oscillating strongly), the 50–60 threshold may provide a useful guide for spring planting. The index can be calculated from local plantation stations or extrapolated from long-term climate stations.[3]

5.3 Planting Time

The earlier the planting of Douglas-fir, the greater its survival and growth.

Timing of planting is important for capitalizing on the vigour of planting stock, as well as on the site and climatic conditions. Even in the most climatically equitable years, those seedlings planted the latest had the poorest survival. Before delaying a planting it is important to anticipate the possible long-term silvicultural costs of delaying planting. The most profitable long-term result may also be the most expensive short-term strategy (e.g., one that involves road plowing). The feasibility of fall planting should also be considered as an alternative to delayed spring planting.

5.4 Plantation Assessment

Early plantation inspection made 6–8 weeks after planting provides a good idea of the success of the plantation.

If survival problems are already evident at an early assessment, plans for corrective measures should be initiated. Site and climatic conditions, as well as stock records, should be inspected to determine the causes of the mortality so that future failures can be prevented. The FWI system may provide useful information on climatic conditions.

Repeating the survival check after a year appears to give a good indication of long-term survival.

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[3] Spittlehouse and Goldstein, 1990.

6 LITERATURE CITED

Bergerud, W.A. 1987. Dose-response models for stand thinning with "Ezjet" herbicide injection system. B.C. Min. For., Victoria, B.C. Res. Note 102.

Burdett, A.N. 1987. Understanding root growth capacity: theoretical considerations in assessing planting stock quality by means of root growth capacity tests. Can. J. For. Res. 17:768–775.

Canadian Forestry Service. 1984. Tables for the Canadian Forest Fire Weather Index System. Environ. Can., Can. For. Serv. For. Tech. Rep. 25. 4th ed.

Cleary, B.D., R.D. Greaves, and R.K. Hermann. 1978. Regenerating Oregon's forests. Oreg. State Univ., Exten. Serv., Corvallis, Oreg.

Hobbs, S. 1988. Seedling performance: past, present, and future needs. *In* Proc. 10th N. Amer. For. Biology Workshop. J. Worrall, J. Loo-Dinkins, and D.P. Lester (editors). Univ. B.C., Fac. For., and Soc. Amer. For., pp. 58–65.

Jolly, R.J. 1985. Techniques for determining seedling water status and their effectiveness in assessing stress. *In* Evaluating seedling quality: principles, procedures, and predictive abilities of major tests. M.L. Duryea (editor). Oreg. State Univ., For. Res. Lab., Corvallis, Oreg., pp. 17–28.

Klinka, K. and M.C. Feller. 1984. Principles used in selecting tree species for regeneration of forest sites in southwestern British Columbia. For. Chron. 60:77–85.

Klinka, K., R.N. Green, P.J. Courtin, and F.C. Nuszdorfer. 1984. Site diagnosis, tree species selection, and slashburning guidelines for the Vancouver Forest Region, British Columbia. B.C. Min. For., Victoria, B.C. Land Manage. Rep. 25.

Krumlik, G.J. and W.A. Bergerud. 1984. Survival and growth of four Douglas-fir stocktypes 21 years after planting. B.C. Min. For., Victoria, B.C. Res. Note 96.

Mullin, R.E. 1974. Some planting effects still significant after 20 years. For. Chron. 50:191–193.

_____. 1980. Comparison of seedling and transplant performance following 15 years growth. For. Chron. 56:231–232.

Pendl, F. and B. D'Anjou. 1983. Survival and early growth of morphologically defined classes of Douglas-fir on high site lands. B.C. Min. For., Victoria, B.C. Report on EP 589.

Pendl, F. and B. D'Anjou. [1990]. Survival and growth of four amabilis fir stocktypes on Vancouver Island. For. Chron. In press.

Pollack, J.C. and P. LePage. 1986. An all-season container and bareroot planting trial of lodgepole pine and white spruce: 14-year results. B.C. Min. For. and For. Can., Victoria, B.C. FRDA Report 4.

Ritchie, G.A. 1982. Carbohydrate reserves and root growth potential in Douglas-fir seedlings before and after cold storage. Can. J. For. Res. 12:905–912.

Scagel, R.K., R.E. Green, R.C. Evans, and H. vonHahn. 1989. Exploratory high elevation reforestation trials in the Vancouver Forest Region: 10-year species performance of planted stock. B.C. Min. For. and For. Can., Victoria, B.C. FRDA Report 098.

Scagel, R.K., G.J. Krumlik, M.J. Goldstein, and R.C. Evans. [1990]. Time of planting of Engelmann spruce in the ESSFwm and MSdm2 in the Lillooet Forest District, British Columbia. B.C. Min. For. and For. Can., Victoria, B.C. FRDA Report. In press.

Sloan, J.P. 1989. Fall-lifted Douglas-fir outperforming spring-lifted stock 13 years after planting. Tree Planters' Notes 40(3):20–24.

Stein, W.L. 1978. Reforestation evaluation. *In* Regenerating Oregon's forests. B.D. Cleary, R.D. Greaves, and R.K. Hermann (editors). Oreg. State Univ., Exten. Serv., Corvallis, Oreg., pp. 206–221.

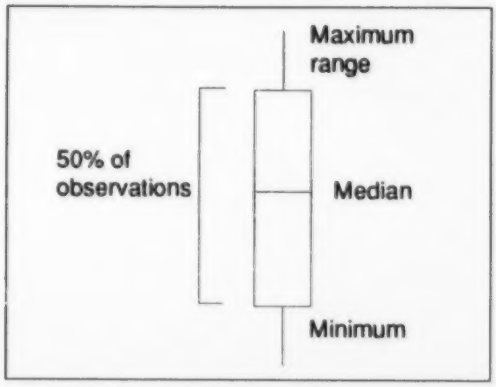
Thompson, C.F. 1974. Tenth-year remeasurements of planting trials with ponderosa pine. B.C. Min. For., Victoria, B.C. Res. Note 65.

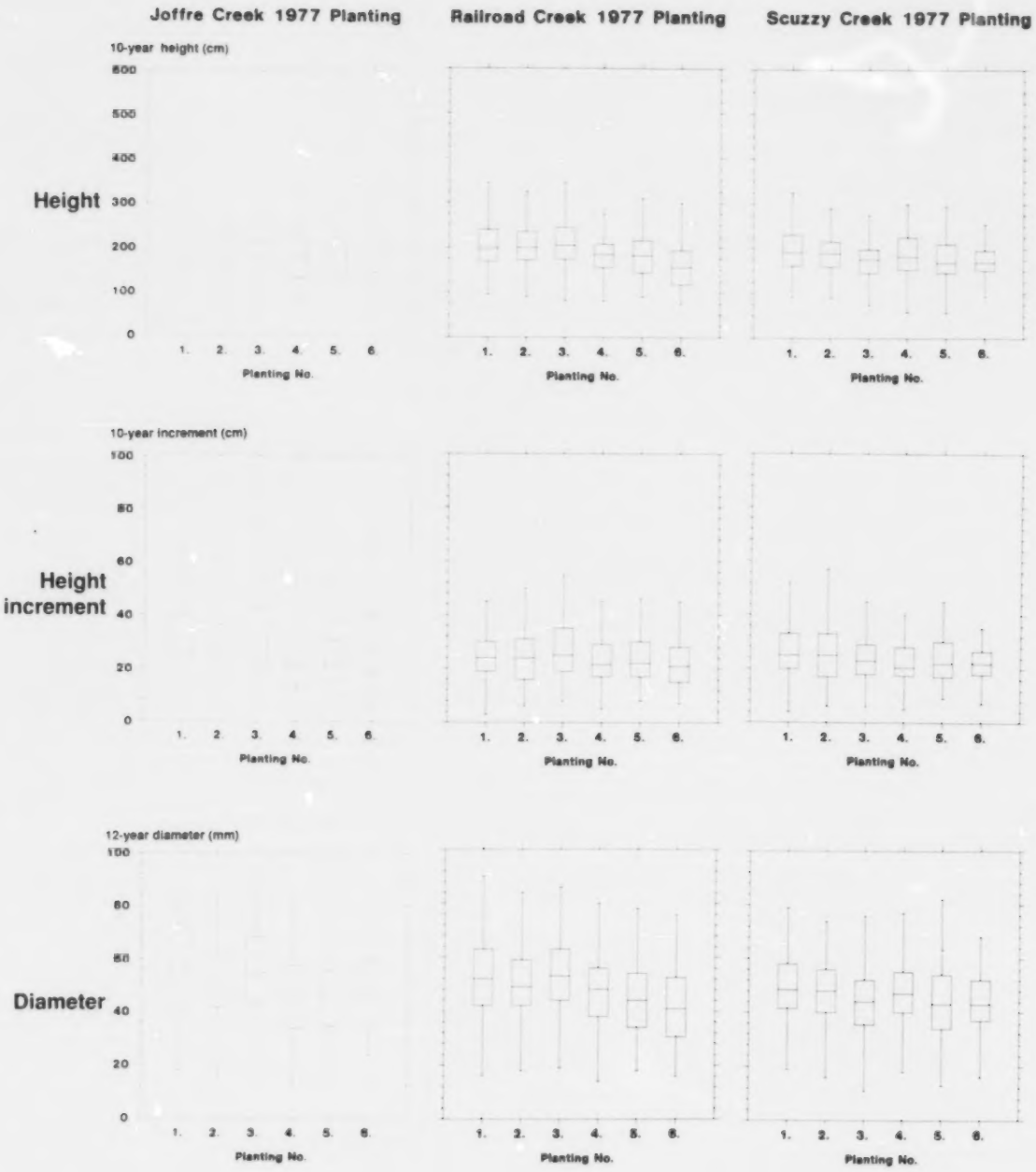
Titus, S.J. 1987. A graphic approach to summarizing forestry data. For. Chron. 63:347–350.

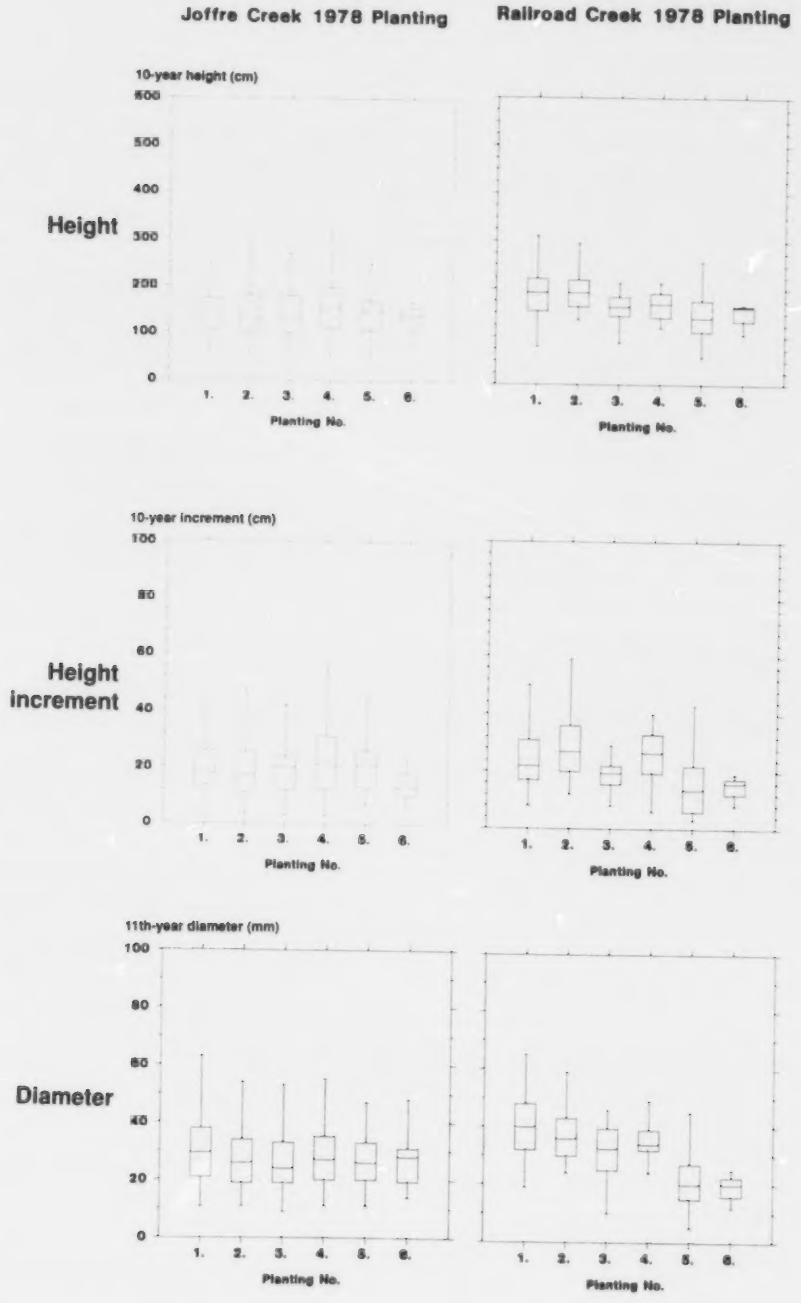
Turner, J.A. and B.D. Lawson. 1984. Weather guide for the Canadian Forest Fire Danger rating system. Can. For. Serv. BC-X-177. Revised.

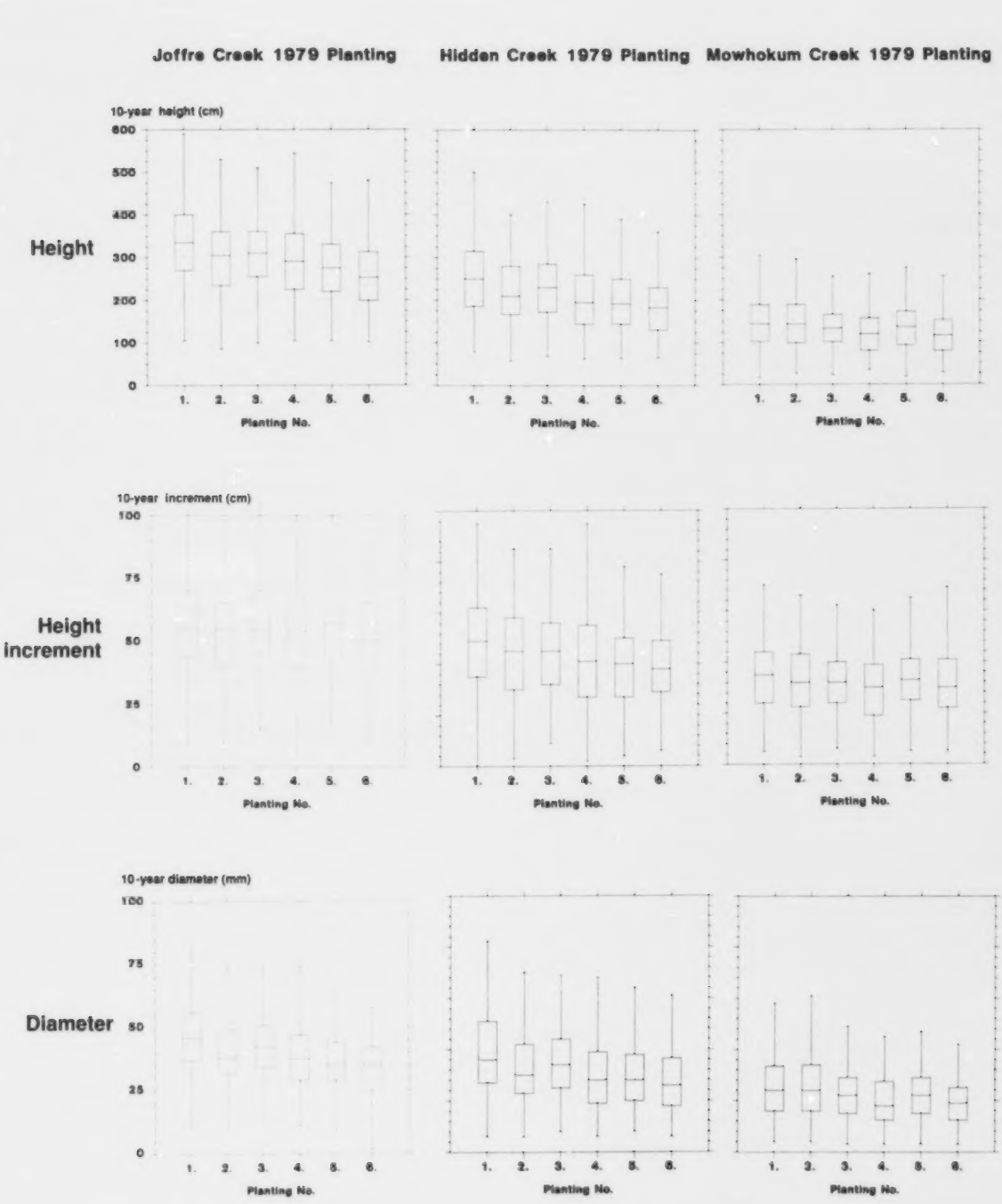
APPENDIX 1. Location-specific growth

Box plots of planting dates for 10-year total height, 10-year height increment, and total diameter in 1988. Box plots pool all sites and rows at a location for each planting date at a location. Inset describes box plot graphing conventions.




Joffre Creek 1977 Planting
Railroad Creek 1977 Planting
Scuzzy Creek 1977 Planting
10-year height (cm)
Height
10-year increment (cm)
Height increment
12-year diameter (mm)
Diameter
Planting No.


Joffre Creek 1978 Planting
Railroad Creek 1978 Planting
10-year height (cm)
Height
600
500
400
300
200
100
0
1. 2. 3. 4. 5. 6.
Planting No.
10-year increment (cm)
Height increment
100
80
60
40
20
0
11th-year diameter (mm)
Diameter


Joffre Creek 1979 Planting
Hidden Creek 1979 Planting
Mowhokum Creek 1979 Planting
Height
10-year height (cm)
600
500
400
300
200
100
0
1. 2. 3. 4. 5. 6.
Planting No.
Height increment
10-year increment (cm)
100
75
50
25
0
Diameter
10-year diameter (mm)